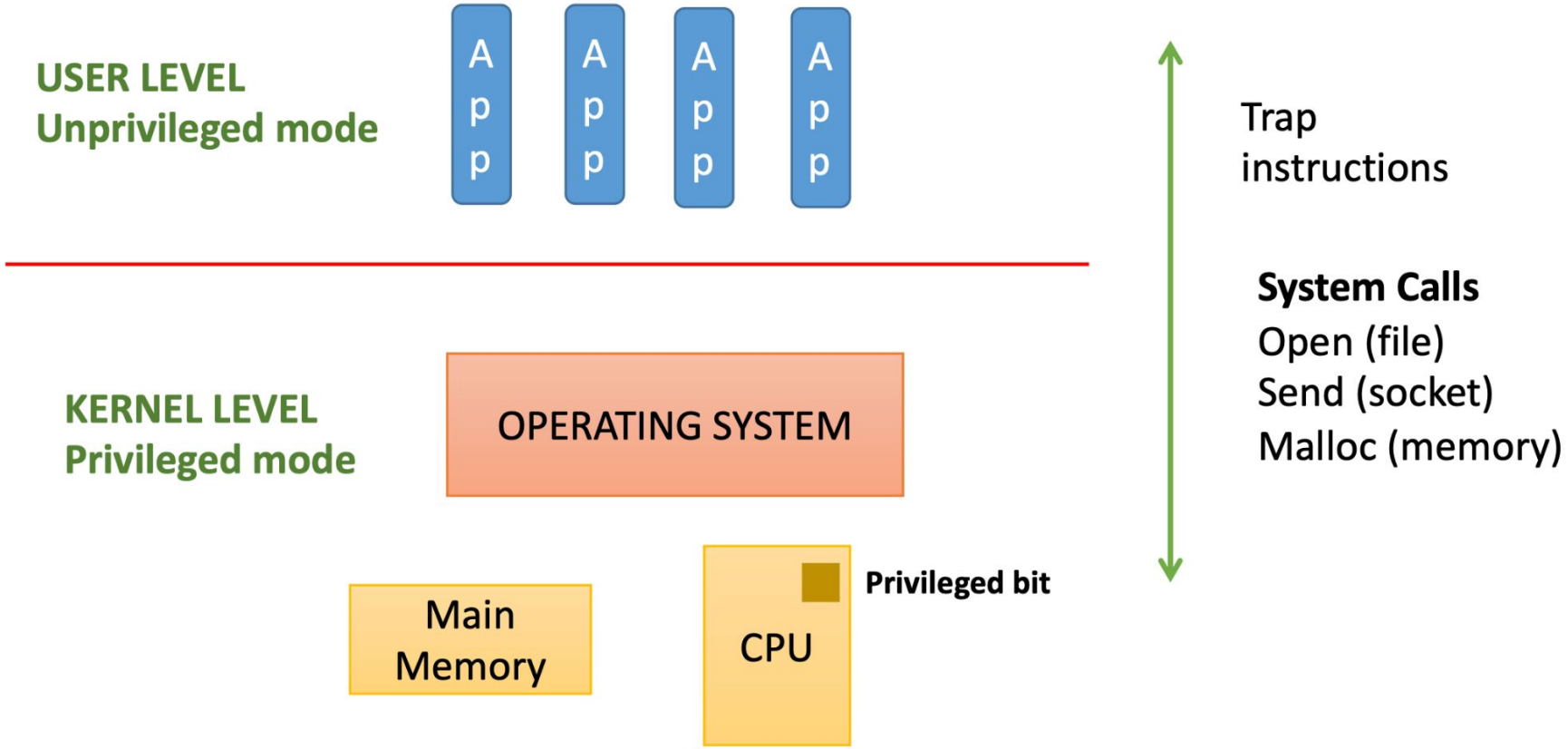
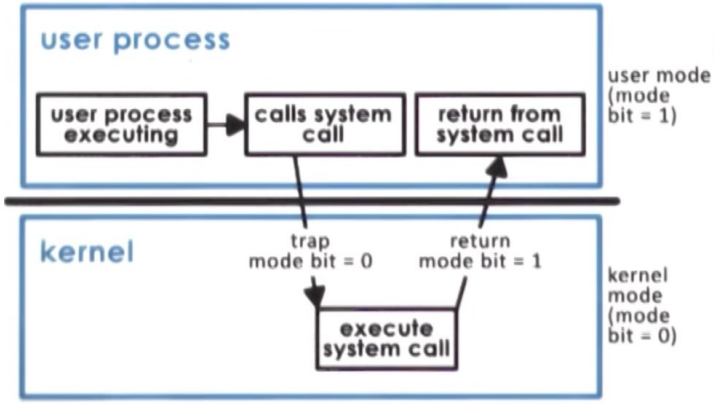
Recap

- Bootloader
- User/Kernel space
- System calls
  - Trap tables
- PA0 ✅
- PA1 🔁

User/Kernel Protected Boundary



System Call Flow

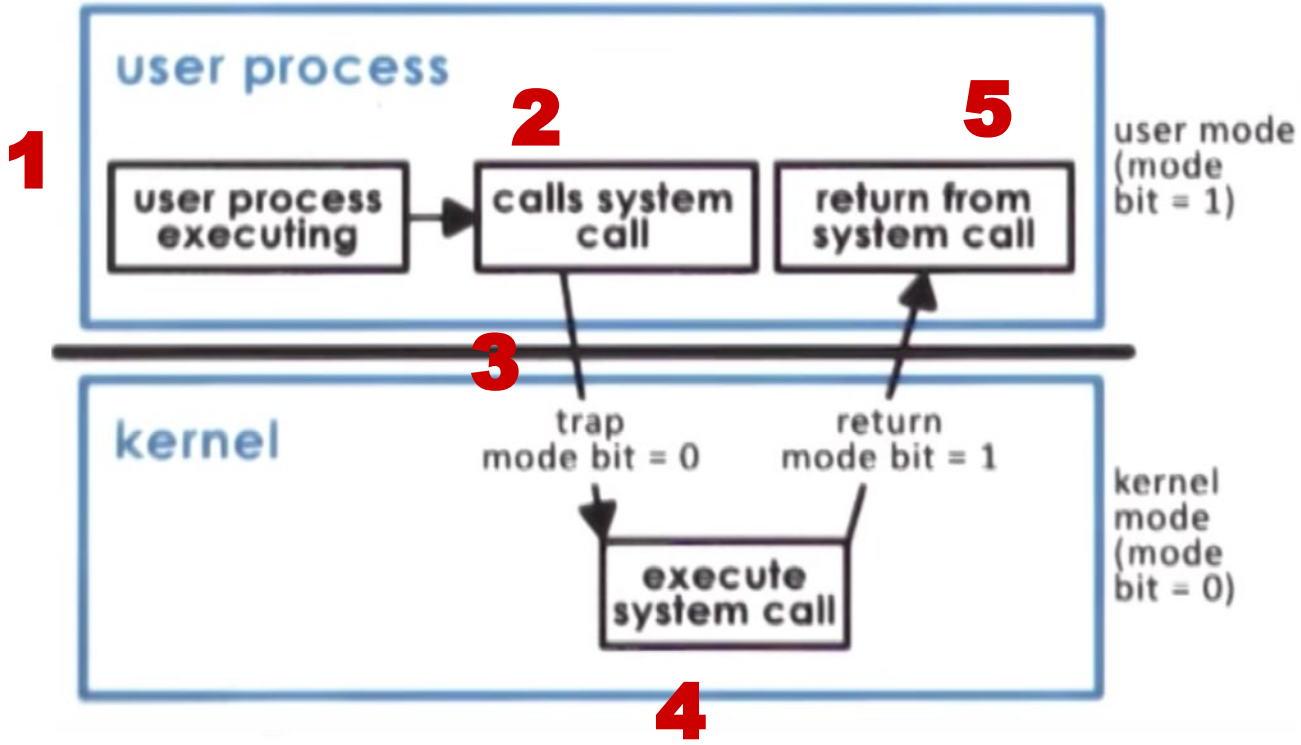


- To make a system call a program must:
  - write arguments
  - save relevant data to a defined location
  - make call using the specific system call number

Executing System Call

1. A user space program invokes the syscall
2. A (usually) software interrupt is called and a trap is triggered (INT)
3. Mode bit is flipped from user to kernel (1 to 0)
4. The interrupt informs the kernel which syscall is needed
    a. Requisite data is retrieved
    b. Kernel verifies if all parameters are valid before executing the syscall
5. After execution, mode bit flips and user program resume

System Call Flow



Adding A System Call

1. Write the system call source code
2. Add the new syscall to the Makefile
3. Add the syscall to the syscalls table
4. Add the syscall prototype to the syscalls header file
5. Recomile, install, boot into mod'd kernel

Adding A System Call

1. Write the system call source code

```
#include <linux/kernel.h>
#include <linux/linkage.h>
#include <linux/syscalls.h>

SYSCALL_DEFINE0(helloworld)
{
  printk(KERN_ALERT "hello world\n");
  return 0;
}
```

2. Add the new syscall to the Makefile
3. Add the syscall to the syscalls table
4. Add the syscall prototype to the syscalls header file
5. Recomile, install, boot into mod'd kernel

Adding A System Call

1. Write the system call source code
2. Add the new syscall to the Makefile
   a. within ‘./arch/x86/kernel/Makefile’ add the line:

```
obj-y+=helloworld.o
```

3. Add the syscall to the syscalls table
4. Add the syscall prototype to the syscalls header file
5. Recomile, install, boot into mod’d kernel

Adding A System Call

1. Write the system call source code
2. Add the new syscall to the Makefile
3. Add the syscall to the syscalls table
   a. Within file ‘./arch/x86/entry/syscalls/syscall_64.tbl’ add:

```
447     common  helloworld                sys_helloworld
```

4. Add the syscall prototype to the syscalls header file
5. Recomile, install, boot into mod’d kernel

Adding A System Call

1. Write the system call source code
2. Add the new syscall to the Makefile
3. Add the syscall to the syscalls table
4. Add the syscall prototype to the syscalls header file
   a. Within the file ‘./include/linux/syscalls.h’ add the line:

```
asmlinkage long sys_helloworld(void);
```

5. Recomile, install, boot into mod’d kernel

Adding A System Call

1. Write the system call source code
2. Add the new syscall to the Makefile
3. Add the syscall to the syscalls table
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5. Recomile, install, boot into mod'd kernel

```
cd /home/kernel/linux-hwe-5.13-5.13.0
make -j10
sudo make modules_install
sudo make install
sudo reboot now
```

Loadable Kernel Module (LKM)

- LKM is a chunk of code we add to the Linux kernel while it is running

- Most often we do this with these modules:
  - Device drivers
  - Filesystem drivers
  - System calls

Loadable Kernel Module (LKM)

- LKMs are part of the kernel, once loaded
  - The part of the kernel bound to the machine image on boot is “base kernel”

- LKMs communicate with the base kernel

Why Use LKMs?

- We DON’T have to rebuild the kernel
- Help diagnose system problems
  - A device driver bug could bring down the kernel/entire system
- Save memory
  - Only load kernels when necessary
- Much faster to maintain, debug, and deploy

LKM Utilities

- insmod - insert LKM into kernel
- rmmod - remove LKM from kernel
- lsmod - list currently loaded LKMs
- kernels - kernel daemon program (for automation)
- modprobe - ins/rm one or multiple LKMs intelligently
  - e.g., if mod A must be loaded before mod B, modprobe will automatically load mod A if you request mod B
- depmod - determine mod interdependency
- ksyms - display symbols exported for the new LKM
- modinfo - displays LKM info from .modinfo section of LKM obj file

How to Add LKM

1. Write LKM code
2. Add module to Makefile
3. Compile the module to get the .o file
4. Insert the mod into the running kernel

How to Add LKM

1. Write LKM code

Create a directory, **/home/kernel/modules**, and edit a new file named **helloModule.c**. Populate this file with the following code:

```
#include<linux/init.h>
#include<linux/module.h>

MODULE_AUTHOR("Your Name");
MODULE_LICENSE("GPL");

int hello_init(void) {
  printk(KERN_ALERT "inside %s function\n",__FUNCTION__);
  return 0;
}

void hello_exit(void) {
  printk(KERN_ALERT "inside %s function\n",__FUNCTION__);
}

module_init(hello_init);
module_exit(hello_exit);
```

2. Add module to Makefile
3. Compile the module to get the .o file
4. Insert the mod into the running kernel

How to Add LKM

1. Write LKM code
2. Add module to Makefile

```
obj-m:=helloModule.o
```

3. Compile the module to get the .o file
4. Insert the mod into the running kernel

How to Add LKM

1. Write LKM code
2. Add module to Makefile
3. Compile the module to get the .o file

```
make -C /lib/modules/$(uname -r)/build M=$PWD
```

4. Insert the mod into the running kernel

How to Add LKM

1. Write LKM code
2. Add module to Makefile
3. Compile the module to get the .o file
4. Insert the mod into the running kernel

```
user@csci3753:/home/kernel/modules$ sudo insmod helloModule.ko
user@csci3753:/home/kernel/modules$ lsmod | grep hello
helloModule 16384 0
```

Much faster!

Passing Data Safely Between User/Kernel Space

- copy_from_user
- copy_to_user
- strnlen_user
- strncpy_from_user
- get_user
- put_user

Where are we getting this from? Kernel Memory Access PDF on Canvas

PA1

- What questions do you all have?
- How many people have already finished?
- What has been the hardest part to complete?